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Subject: Letter Progress Report of Work under Contract No. NASr-54(06) for the Period 1 December 1964 to 28 February 1965

Gentlemen:

This status report covers work during the period 1 December 1964 to 28 February 1965 under Contract No. NASr-54(06), Man-Machine Performance Measurements. By the end of this period approximately 70% of the budgeted funds for the first year have been expended. The first year contract formally runs from 1 March 1964 to 28 February 1965 but because of delayed final negotiations and delays in project initiation, work actually started on or about 1 June 1964. As a result a no-cost extension of the first year's work has been requested to 30 June 1965. The second year's funding is to begin as of 1 July 1965.

Experimental work on human performance characteristics and equipment development for conduct and analysis of experiments are continuing as indicated below.

1. EXPERIMENTAL STUDIES

Three-State Relay Control Studies

Data collection and analysis of the three-state relay control study investigating display of explicit velocity information is complete. This experiment is being written up for presentation at the May meetings of the Sixth Annual Symposium on Human Factors in Electronics in Boston.

A second study in this series (65-1) has been designed and initiated. In this experiment further evaluation of the time necessary to process visual feedback is being explored. It was found in the previous study that operators who were required to control a pure acceleration system by actuation of two response keys that applied a simulated force to the pure inertial system, rapidly converged on the strategy of using brief pulses to provide small increments in output velocity and position after nulling out the initial error. Capitalizing on this behavior, it was determined that a potentially useful measure of the time necessary to make control decisions could be derived from examining the interresponse time following the occurrence of these brief pulse responses. If a pulse is arbitrarily defined to be a response of duration less than 120 millisec., then essentially no evaluation of pulse effectiveness can be carried out during the pulse duration itself. Thus the time following each pulse must be spent deciding what to do next. In the previous study the modal time necessary to determine the effectiveness of the last response and to initiate the next action was in the range of 300 millisec.

In order to verify that this interresponse time is, in fact, contingent on visual information available after the pulse and to further assess the relationship between the availability of visual information and decision time, four of the subjects from the previous experiment are being recalled to perform the same task with a new constraint added. Whenever the operator completes a response meeting the definition of a pulse, visual information is withheld momentarily, that is, the display is blanked for a brief period following each pulse. The experimenter has control of the duration of blanking (ranging from 170-410 millisec.) and the delay between the occurrence of the pulse and the onset of blanking (ranging from 68-335 millisec.). In a series of sessions all subjects will perform with all combinations of three values of blanking and three values of delay. As before, the variable of interest will be the distribution of response times following pulses. If these times represent feedback processing time, it should be possible to manipulate the position and shape of the distributions by the introduction of blanking. This kind of data should prove very useful in forming a bridge between the concepts of information processing in discrete tasks and theoretical formatulations of continuous control behavior. It has the potential of making the discrete time measurement useful in the continuous control case thus providing a sensitive measure of the effect of task variables on performance.

Controller Performance With Predictable Input Signals

The data collection for the study of operator performance with sine wave input signals (65-2) is two-thirds complete. In this experiment three subjects are being given extensive training (32 one-hour daily sessions) at tracking pure sine waves at five frequencies: 0.09, 0.50, 1.03, 2.07 and 4.0 cps. During training each subject is completing eight four-day blocks of practice. Each block includes all combinations of the following independent variables:

Independent Variable	Parameter Constants
Display Gain	7.5, 15.0 volts/cm
Control Gain	1.42, 3.12 deg/volt
Control Stick Spring Constant	.0235, .0645 lbs/deg
Display Mode	Pursuit, Compensatory
Input Peak Amplitude	30 volts

Subjects are provided with augmented feedback beyond that provided by their visual display by listening to a tone whose pitch is proportional to the integrated-absolute-error averaged over a 2 sec. period.

In addition to integrated-absolute-error scores, data are being recorded on magnetic tape for further analysis and graphic records of the critical output variables are being obtained. A power spectrum analyzer is being programmed on an analog computer which can be used for on- and off-line signal analysis. It is planned to obtain power spectral estimates from subjects output position and velocity signals. Consideration is also being given to the usefulness of an integrated-absolute-velocity-error signal derived from the difference between the operator's desired and actual velocity output.

It is our belief that any general theory of manual control behavior must be able to represent and predict performance in control of predictable input signals of which sine waves are a special case. This study will make a contribution toward describing in considerably greater detail then has previously been possible what some of the phenomena of predictable signal tracking are that need to be represented in a theory or model.

Planning has been initiated for a second series of studies of predictable input signals. In study 65-3 a specific movement pattern lasting less than five seconds will be selected and subjects will be trained to perform this specific movement in several different modes. In the visual mode they will be required to follow the pattern as presented in a pursuit display on an oscilloscope. In the kinesthetic mode they will be required to watch the pattern passively and then reproduce it by feel alone. In the slow-motion mode they will track the same amplitude pattern scaled longer in time by a factor of two or four. Criterion performance will be judged in terms of the ability to make the precise movement in position and velocity in the absence of visual information. These modes will be considered separately and in combination in order to evaluate the effectiveness of each mode for training precise predictable movements. The applicability of these data range from the training of athletic skills to precise space-vehicle maneuvers.

2. RESEARCH FACILITY DEVELOPMENT

Pseudo-Random Noise Generator

Design and construction of the pseudo-random noise generator described in the last progress report has been completed and detailed investigation of its output amplitude distribution and power spectrum have been initiated. It appears that the driving frequency of the shift register and the cut-off frequency of the analog filter that converts the binary pulse train into a continuous signal interact critically in defining the shape of the output amplitude distribution.

90 Amplifier Repetitive-Operation Analog Computer

The Information and Control Engineering Laboratory has had under development for a number of years a large analog computer which is being used in support of this and other projects. This computer was designed and built by laboratory staff members and is more or less continually under development. The most recent modifications which have been supported in part by this project, include installation of extensive digital logic modules which will greatly improve its flexibility and will make it capable of performing in a repetitive operation mode. It is this machine on which the spectral analysis programs, orthornormal filter programs, etc. are being implemented.

3. RELATED WORK

Conference on Manual Control

On December 3rd through 5th the Michigan-NASA Annual Working Conference on Manual Control was held at the Rackham Building on the University campus. Seventy-three of seventy-five invitees representing industrial, government and university laboratories participated. Approximately 35 presentations were given in 7 morning, afternoon and evening sessions, on topics ranging from applications of quasilinear describing function analysis to the manned booster problem, to consideration of physiological variables of importance for understanding manual control performance. Sessions included: Development of human operator models, manual control analysis and measurement technique, human performance and piloted simulation studies, and application of manual control theory. Discussion was wide ranging and effective in highlighting the issues facing further development and application of manual control theory and principles. Participants agreed that the conference was effective in promoting informal information exchange and it is recommended that further conferences of this type be held in the future.

Personnel

The following personnel have worked under this contract during this reporting period.

	Fraction of Time
R. M. Howe	.10
P. M. Fitts	.10
R. W. Pew	.50
J. Duffendack	.40
J. Frait	.50
R. Zauel	.25
L. Kiplinger	1.00
R. Rapley	.50

Sincerely yours,

R. M. Howe

R. M. Howe

R. W. Pew

R. W. Pew

Co-Principal Investigators

RWP/mr